Rare-earth Information Center

Insight

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Superconducting Current Leads for Maglev

Most of us have seen or at least seen pictures of a Nd-Fe-B magnet floating above a disk of high temperature superconductor. As a result, when the concept of superconducting magnetic levitation trains (Maglev) is mentioned, it is often assumed that this is the effect that will be used. This is, in fact, false for some very practical reasons. Clearly, rare-earth producers would love to see kilometers of track made from Nd-Fe-B magnets or $YBa_2Cu_3O_7$ superconductors, however, aside from the expense, if the tracks were magnets, all kinds of junk and small cars would stick to them while the prospect of maintaining the track at liquid nitrogen temperature is also not appealing. In practice, the track has coils of normal conductor imbedded in it, and the train has high field superconducting magnets. When the train is moving, the field produced by the magnets induces eddy currents in the coils, resulting in an opposing field that levitates the train. In this scenario, the refrigeration system for the superconducting magnet must be on board the train, and thus its mass is important. The major factor, which determines the heat leak into a superconducting magnet and hence the size of the refrigeration system, is the thermal conductivity of the current leads for the magnet. In a typical laboratory magnet system, these leads are copper, and they must be cooled by He gas. Bi-Sr-Ca-Cu-O current leads are now available; however, they are not suitable for Maglev applications, which require that the current leads experience high fields, and the current carrying capacity of Bi-Sr-Ca-Cu-O in field is notoriously bad. As a result, RE-Ba-Cu-O current leads are required. While such leads can be fabricated, they must be essentially single crystals. These crystals are quite brittle and always contain microcracks and other defects. As a result, the mechanical properties are poor. Given the fact that, for Maglev applications, these leads must survive in a moderately high vibration environment, mechanical stability is a major problem. Recently, M. Tomita et al. {*Physica C*, **357-360**, 832-6 (2001)} have significantly improved the mechanical strength of monolithic YBCO current leads by vacuum impregnating them with resin and quartz fiber reinforcements. The process resulted in a 30% increase in the strength of the material. Notably, the deterioration normally observed in these materials with thermal cycling was eliminated. The fracture mechanism for brittle materials containing microcracks results from extremely high stress intensities at the crack tip. If the sides of the crack move apart, this stress exceeds the yield strength, and the crack tip advances. By filling all major cracks and voids with resin, the sides of these defects are constrained, reducing the stress at their tips or corners and greatly reducing crack propagation.

Improved Infrared Process Heaters

Infrared heaters are used in a wide variety of processes from drying paint to setting thermoplastics. The efficiency of the heating depends on the ability of the heater to stimulate the absorption bands of the material, which for many organics are in the midinfrared range. Typical heaters consist of heating coils imbedded in white aluminosilicate ceramic (mullite) because of the need for good mechanical properties at 1000 K. The problem is that these materials have very poor spectral emissivity in the midinfrared range. In order to enhance the emissivity of the heater and hence the efficiency of heating, it is desirable to coat the aluminosilicate ceramic with a high emissivity coating. This requires that the coating adhere to the ceramic through numerous thermal cycles. Recently, B. Rousseau et

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al. (*Appl. Phys. Lett.*, **79**, [22], 3633-5 (2001)} have developed a technique involving spray pyrolysis and rapid thermal annealing to deposit a rough, high surface area Pr_2NiO_4 coating on sintered cordierite mullite. Pr_2NiO_4 is a highly anisotropic material related to the high temperature superconducting Cu-O materials. This material has an interesting emission spectrum as a result of the coupling of the ions in the lattice to the charge carriers induced by oxygen excess. The technique developed to produce an adherent coating involves creating an aerosol mist of a 0.05 M aqueous solution of praseodymium nitrates mixed with nickel nitrates. A carrier gas transports the droplets, which are ~10 μm in diameter, to the surface of the substrate that is at 850°C. This deposits a precursor, which was then crystallized at 1100°C. The resulting coating results in an increase by a factor of five of the emissivity in the desired range.

Chinese Rare Earth Cemented Carbides

Tungsten carbide (WC) is a very hard but brittle material. In order to make a useful tool bit, it is necessary to reduce the WC to a micron sized powder and then "cement" the powders together. In their simplest form, cemented tungsten carbides are produced by blending the WC powder with Co powder and pressing and sintering the part. The Co serves as a liquid phase sintering aid that wets the particle surfaces and through capillary forces pulls the WC particles together. The ductile Co on the grain boundaries toughens the part. The hardness, wear resistance, and toughness, which equates to shock resistance, can be tailored to a particular application by varying the ratio of WC to Co and by various additives to the Co. One class of highly effective additives is the rare-earth elements. La, Ce, Pr, Nd, Sm, Gd, Dy, and Y have all been investigated. The RE has been added as metal, oxide, hydride, carbide, carbonate, and nitrate. Various combinations of the above have also been investigated. The development of RE cemented carbides in China has recently been reviewed by C. Xu et al. {*Int. J. Refractory Met. Hard Mater.*, **19**, 159-68 (2001)}. The incorporation of RE in cemented carbides can produce 50 –100% improvement in tool life over the corresponding non RE containing carbide, but the effectiveness of the additions is highly dependent not only on the RE and the chemical form of the RE addition, but also on how the addition is incorporated in the process. In the production of cemented carbides, the WC and Co are wet milled together in order to produce a uniform mixture. Clearly, if the RE addition is made in the wet milling process, the final chemical form of the RE may be quite different from the starting form. As a result of these uncertainties, there is no agreement on the optimum RE content between various laboratories. The paper discusses a wide variety of cemented carbide grades. An appendix gives the ISO equivalents for the various Chinese grades.

Photoinduced Spectral Change in Eu_2O_3

The photoluminescence spectra of Eu_2O_3 normally consists of a red sharp-line structure. However, recent measurements by S. Mochizuki et al. {*Appl. Phys. Lett.*, **79**, [23], 3785-7 (2001)} have shown that when Eu_2O_3 is irradiated with ultraviolet (UV) laser light in a vacuum, the spectrum changes to a white broad band. This state appears to be metastable, as the behavior persists unchanged for periods of months at room temperature when the sample is exposed to air or other atmospheres. Irradiating the sample a second time under an O_2 atmosphere results in a return to the original spectrum. While these changes were observed for a laser wavelength λ= 325 nm over a broad range of power densities, 14 other values of λ failed to produce spectral changes. Thirteen of these wavelengths were longer (lower energy) than the critical wavelength, but one was shorter. Thus, there appears to be a critical energy for excitation into the excited state. The broad band emission is believed to be associated with the formation of Eu^{2+} ions and local structural changes arising from oxygen defects. Given the large difference in magnetic moment between Eu^{2+} and Eu^{3+}, it would be interesting to study the magnetization of the materials.

Sincerely,

R. W. McCallum
Director of RIC